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Technical Report on Meteorology No. 1

Atmospheric Oscillations and Related Synoptic Patterns

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Atmospheric Oscillations and Related Synoptic Patterns

by

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ABSTRACT

Records from sensitive microbarovariographs installed at Palisades, N. Y., Columbia University in New York City, and the U.S. Merchant Marine Academy, Kings Point, L. I. have been studied in connection with synoptic and local weather data. A number of interesting pressure events have been noted in connection with the passage of certain synoptic situations. These include pressure jump lines, squall lines, cold fronts and thunderstorms. Low level turbulence or convection associated with certain air masses at certain times is well-recorded by short-period pressure variations. Conclusions regarding the origin of squall lines are drawn from the empirical evidence given.

INTRODUCTION

In the course of study of atmospheric micro-oscillations as a possible source of microseisms several effects of apparent meteorological significance were noted which suggested further investigation. This is a preliminary report of some of the results of this work. The instruments used are similar to the microbarovariograph described by Ewing and Press (1) in which equal hollow cylinders, one being open to the air and one sealed, are balanced at opposite ends of a horizontal boom. Changes in buoyancy accompanying changes in pressure produce oscillations of the sensitive element which are recorded photographically after amplification through an electromagnetic transducer and galvanometer. Hollow glass flasks have since been substituted for the cylinders with a resulting increase by a factor of five of the sensitivity indicated in the published calibration curve. The range of periods to which the instrument responds is about 1/2 to 40 min. A slow leak which acts as a filter to eliminate short period variations may be used on the open flask. The one commonly used essentially cuts off periods below 4 min.

Owing to the method of amplification and recording, the microbarovariograph records the rate of change of pressure rather than the pressure. Consequently oscillations on the variogram are out of phase with the actual pressure oscillations by 90 degrees. A pressure increase shows as an up-displacement on the trace, and a decrease as

a down-displacement. Each full line on the variogram represents one hour and breaks at minute intervals are programmed on each line.

Most of the pressure data used in this report are taken from instruments installed at the Lamont Geological Observatory, Palisades, N. Y. and at the Columbia University campus in New York City. Reference is also made to records made by an instrument placed at the U. S. Merchant Marine Academy, Kings Point, Long Island. The relationship among these stations is shown in Figure 1. A report on use of this tripartite network to obtain velocities and directions of motion of significant pressure oscillations will be made separately.

The oscillations described in this report are those associated with pressure-jump lines, squall lines, cold fronts, thunderstorms and low level convection and turbulence. The term pressure-jump lines is used in the sense described by Tepper (2). The squall lines are those analyzed on U. S. Weather Bureau maps and which have the characteristics described by Brunk (3) and Williams (4). In view of this fairly new method of study, actual case histories are given to illustrate the data.

DATA AND DISCUSSION

Case I. A portion of the Palisades microbarovariogram is illustrated in Figure 2, in which two prominent half-wave or positive amplitude disturbances are evident about 0200, June 7. (All times used in this report are GMT.) It must be realized here that this signature does not represent a pressure oscillation in the air, but rather a surge without immediate return. This might occur with the passage aloft of a pressure plateau on a discontinuity surface between lower cold and upper warm air. The period of the half-wave would be an inverse function of the slope of the edge of this pressure plateau, and as soon as actual velocity data become available from the tripartite station, the actual slope of this surface will be determined. The second oscillation just after 0200 resolves the jump into two surges. The total jump time is about 17 minutes with each surge being 8.5 minutes. The conventional Friez microbarogram (inset in Figure 2) shows a small, non-reportable pressure jump at 0200. A longer series of much weaker although full-wave oscillations is indicated about 0500.

An explanation of these pressure events can be found in the synoptic and local weather data. The map for June 7 at 0630 (Figure 3) shows a squall line just past the station at "P". According to the local New York City observations thundershowers began at 0520 although

a ten-minute light rain occurred an hour earlier. These showers apparently mark the passage of the squall shown on the map. The long, weak train of oscillations on the variogram at 0500 probably is indicative of convection attending the passage of the squall.

The pressure-jump at 0200 definitely precedes the passage of the squall. Local observations show a gusty wind shift from south to north between 0100 and 0200 coinciding with the time of the surge. If this surge was genetically related to the squall line, it must have outrun the latter by two to three hours. Earlier maps show no other squall or obvious synoptic feature that could have been related to this pressure-jump. Brunk (5) has already shown the existence of traveling lines of pressure pulsations without related squall lines. The data seem to support Tepper's model of a pressure-jump (2) as being a traveling wave or plateau on a discontinuity aloft. The data however conflict with the notion that the squall-line and pressure-jump line are coincident and inseparable phenomena. It is suggested in this present case that the pressure surge aloft may have passed through a zone of instability and thereby provided the necessary forced convection to trigger the squall formation. The disturbance on the discontinuity then traveled ahead with a velocity depending on factors other than those which control the movement of synoptic patterns. Crawford (6) has already made a synoptic study of certain instability lines and their cause.

Case II. The Palisades variogram and standard Friez barogram for May 13-14, 1953 are illustrated in Figure 4. The Friez record shows a pressure-jump at 2400, May 13. The Palisades record shows this very strikingly beginning with the pressure surge at 2400 and followed by two weaker surges about one-half hour later. The prominent irregular short-period oscillations evident before the surge from 1600 to 2400 are notably absent following the 2400 pressure change. The Palisades trace further shows about two hours of low-amplitude, long-period oscillations beginning between 0600 and 0700, May 14. The major features of the variograms from Palisades, Columbia campus and Kings Point are much the same, but show appropriate time differences.

The weather map (Figure 5) shows a cold front in the immediate vicinity of the station "P" on May 14 at 0630. The inset map for the time 12 hours earlier shows the front well to the west and preceded by an area of showers which may represent a squall not analyzed on the map. This idea is supported by the "past weather" observations on the 0630, May 14 map, which show that thunder-showers generally preceded the cold front along the coast. Local observations (New York City) show a wind shift from southeast to north at 2400, May 13, the time of the strong oscillation on the pressure record. Although no showers fell at Palisades, showers at New York City started one hour later. The wind returned to the south between 0100 and 0200.

The synoptic picture and local observations indicate the passage of a squall line at approximately 0100, May 14. The first pressure

surge preceded the squall by about one hour, a relationship similar to that noted in the preceding case.

Although the wind returned to the south between 0100 and 0200, following the passage of the squall, the short-period oscillations did not recommence and seem related to the passage of the squall rather than the cold front seven hours later. Roshke (7) and Clark (8) studied pressure fluctuations in this range of frequencies using short-period instruments. According to the former, transitions from active to quiet occurred with cold front passage rather than squall or pressure-jump passage. In the present case the sky was overcast prior to 1600, May 13 with a change to clear to scattered clouds until the squall passage following 2400. The sky remained overcast for the following day after the squall passage and during the time of the remainder of the record. This correlation suggests that the short-period pressure oscillations are low level turbulence or convection phenomena dependent on solar heating of the surface.

The two hour interval of long, low oscillations beginning after 0600, May 14 seem to coincide with the time of, or occur just after cold frontal passage. This is a common phenomenon attending the passage of cold fronts and may represent convection in the frontal zone or waves on the frontal surface aloft. No showers or rain were associated with the passage of this front. If the oscillations are features of the frontal zone, they are indicative of the width of this zone. As soon as velocity data become available this width can be given quite accurately.

Case III. A strong full-wave oscillation is evident on the Columbia variogram beginning 0115, April 11 (Figure 6). This event shows on the Palisades record (about 15 mi. to the north) with only one-third this amplitude.

According to surface maps in Figure 7, a cold front has passed the station "C", between 0030 and 0630, April 11. New York City observations(taken about 5 mi. to the south of "C") show that the wind shifted from E to NW between 0100 and 0200 and remained so. This shift, with other observational criteria mark frontal passage. Preceding frontal passage smoke or fog with rain or drizzle persisted for 15 hours indicating fairly stable conditions. Local observations report a thunderstorm, apparently of frontal origin, beginning 0137 and ending 0155. The strong pressure oscillation on the Columbia variogram has a period of about 18 minutes and could mark the convectional pattern of a typical thunderstorm cell, namely a sharp downdraft followed in turn by an updraft and a weaker downdraft. The microbarovariograph may therefore be a useful tool in the study of thunderstorms. It has already been suggested (9) that the pressure recording instruments utilized in the Thunderstorm Project were not sensitive enough to record certain detail of pressure variations and that the availability of appropriate instruments would have led to a better understanding of some storms. The instruments used in this study are believed to be of the order of sensitivity required and may help clarify certain problems related to the structure of thunderstorms and related phenomena.

The weaker signature of this event recorded at Palisades, mentioned above, is probably indicative of the fact that the cell extended laterally for at least a score of miles, although the effects were less pronounced.

Case IV. A squall line is indicated on the map for 0630, May 13 (Figure 8) just west of the station. A slight pressure rise was noted on the Friez record and a small positive half-wave typical of a pressure-jump is evident on the microbarovariogram beginning about 0800 (Figure 9). Surface observations show a wind shift from SE to S and clouds increasing from .4 to 1.0 between 0800 and 0900. The wind shifted back to S by 1000. Rain was reported beginning 0845 and ending 0920. Apparently the squall line passed between 0800 and 0900 coinciding fairly closely with the passage of the weak pressure-jump.

Case V. In contrast to the above situation is the strong pressure surge evident on the Palisades variogram shortly after 0500, June 5 (Figure 10). Although this surge is many times the amplitude of that described above, no squall conditions existed anywhere in the vicinity as can be determined from the 0630 map of June 5 (Figure 11), nor do any show in the "past weather" observations. According to local surface observations, fair weather prevailed at the time, with smoke and later haze. These emphasize the stable conditions existing during the critical interval.

It seems that the intensity of squall conditions does not coincide with the intensity of pressure-jumps. Thus, the weak jump of May 13 at 0800 (Case IV), significant because of associated weather, was not clearly identified by conventional instruments. These observations again suggest that squall intensity is a function of the air stability, and is triggered by the pressure surge. Where the instability is absent the pressure jump may be perfectly free of storm or squall conditions, It appears then, that pressure-jumps in the atmosphere may occur without squalls, or if associated with squalls, they may precede or occur with the passage of a squall.

An interesting negative half-wave, or pressure drop appears just after 2210 on June 4 (Figure 10). This interesting phenomenon has been observed frequently on these records and appears to be a negative pressure-jump. This has been noted by Brunk (5) and others. This fairly common event will be studied in greater detail with the microbarovariograph.

Case VI. The Palisades record for February 27-28 (Figure 12) shows a common sequence of events associated with the passage of a cold front. Short-period oscillations are prominent beginning prior to 1600. By 2400 they disappear and are replaced by a series of much longer-period oscillations. After a quiet of nine hours the short-period fluc-

tuations recur. The weather map sequence for this interval (Figure 12, lower portion) shows a cold front in the vicinity of the station at 1830, February 27. New York City surface observations show a wind shift SW to W between 1600-1700 and rain beginning 1640 and ending 1705. Thus the cold front definitely passed before 1830 and apparently the short-period fluctuations do not subside until several hours following frontal passage. They increase again about 1100 on the following day. According to Roshke (7) the interval of short-period quiet coincides with frontal passage. If local time is considered (EST=GMT-5 hrs.), these short-period fluctuations appear to decay with sunset and recommence with sunrise, and would thus be indicative of low level turbulence or convection as noted earlier in connection with a similar effect.

The longer-period waves of six to seven minutes are clearly post-frontal. Trains of waves of similar period, amplitude and duration have been noted very frequently following the passage of cold fronts when passage was in the evening. Since surface observations show that clear weather prevailed at this time, and since they occurred at night, convection seems to be negated as a factor of origin. They may be a surface effect produced by the passage of internal gravity waves on the frontal surface aloft.

On February 27, official sunset was 2345. This is about the time the long-period waves began. Sudden changes in upper air density have been reported (10) from the barograms on constant level balloons. This

appears to be a real and measurable effect. It is suggested that internal gravity waves on the frontal surface aloft may be set up by the fairly sudden pressure changes of small but measurable magnitude following sunset. Many other cases very similar to this have been noted and will be studied in further detail.

Case VII. The strong pressure surge evident as a high-amplitude half wave on a portion of the Palisades record about 1500, March 19 (Figure 13) seems to just precede the arrival of a slowly-moving cold front (lower portion Figure 13). According to surface observations rain and fog preceded the front, ending at 1700 and indicating fairly stable conditions. A temporary wind shift occurred between 1500 and 1600 from E to NW for less than one hour followed by a shift back to E for two hours. The cold front, in the process of frontolysis according to synoptic data, passed the station at 1900 with a permanent wind shift to NW.

Obviously the strong pressure surge preceded the weak front. In accordance with the concept advanced earlier in this report, the stable conditions existing in advance of the cold front precluded the formation of squall conditions by the passage of the pressure-jump slightly ahead of the front.

SUMMARY AND CONCLUSIONS

1. The microbarovariograph developed at Palisades is far more sensitive to atmospheric pressure changes than conventional instruments, and shows the detail involved in such changes better than any instrument in current use.

2. Typical pressure-jumps are resolved into positive half-waves representing an abrupt surge of pressure, or the passage aloft of a steep gradient on a surface of discontinuity between lower cold and upper warm air; the period of the half-wave is inversely proportional to the steepness of this gradient. Negative half-waves, or pressure drops are noted frequently which, if analagous to the above would represent the passage of a pressure plain or negative plateau.

3. Pressure jumps may occur with or without associated squall lines. In the former case, the pressure jump may precede the passage of the squall line by some hours, or may occur with its passage. Further, the intensity of the jump seems unrelated to the intensity of the squall that may be related. This study suggests that the pressure jump may trigger latent convection as it passes through a zone of instability, and thereby initiate a squall whose velocity may be different from that of the jump. In the absence of such instability only the pressure-jump is noted. Although this study tends to support Tepper's model of a pressure-jump, it varies from the concept that the squall and jump are coincident phenomena.

4. The passage of a cold front may be marked by a long, low train of waves that may persist for several hours and may indicate the width of the frontal zone. This width can be determined very accurately as soon as tripartite velocity data become available. Trains of strong waves of five or more oscillations and about six minute period often occur within a few hours after the passage of cold fronts when such

passage is near sunset. These are tentatively explained as gravity waves on the frontal surface produced by the fairly abrupt subsidence of cooling air aloft, following sunset.

5. Short-period pressure oscillations (less than 1 1/2 to 2 minutes) are usually indicative of low-level convection or turbulence in certain air masses and are related to diurnal variations and cloud cover. Since these fluctuations are not always present they must reflect low level stability conditions.

6. A definite simple convection cell seems to explain the structure of single thunderstorms.

ACKNOWLEDGMENTS

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Miss O. Haselau aided in the drafting of illustrative material.

REFERENCES

1. Ewing, M. and F. Press, "Further study of atmospheric pressure fluctuations recorded on seismographs", Trans. Amer. Geophys. Un. 34:1, 95-100, 1953

2. Tepper, M., "A proposed mechanism of squall lines: the pressure-jump line", J. Meteorol. 7:1, 21-29, 1950

3. Brunk, I., "Squall lines", Bull. Amer. Meteorol. Soc. 34:1, 1-9, 1953

4. Williams, D., "A surface micro-study of a squall-line thunderstorm", Monthly Weath. Rev. 76:11, 1948

5. Brunk, I., "The pressure pulsation of 11 April 1944", J. Meteorol. 6:3, 181-187, 1949

6. Crawford, M., "A synoptic study of instability lines", Bull. Amer. Meteorol. Soc. 31:10, 351-347, 1950

7. Roschke, W., "The relation between air-pressure micro-oscillations and concurrent synoptic patterns", J. Meteorol. 9:3, 213-219, 1952

8. Clark, R., "An investigation of certain short-period atmospheric micro-oscillations", J. Meteorol. 10:3, 179-186, 1953

9. Bleeker, W. and Andre, M. J., "Convective phenomena in the atmosphere, J. Meteorol. 7:3, 195-209, 1950

10. Smith, J. R., "Constant level balloons, section 3", Tech. Rep. No. 93.02, Research Division, College of Engineering, New York University, July 1949

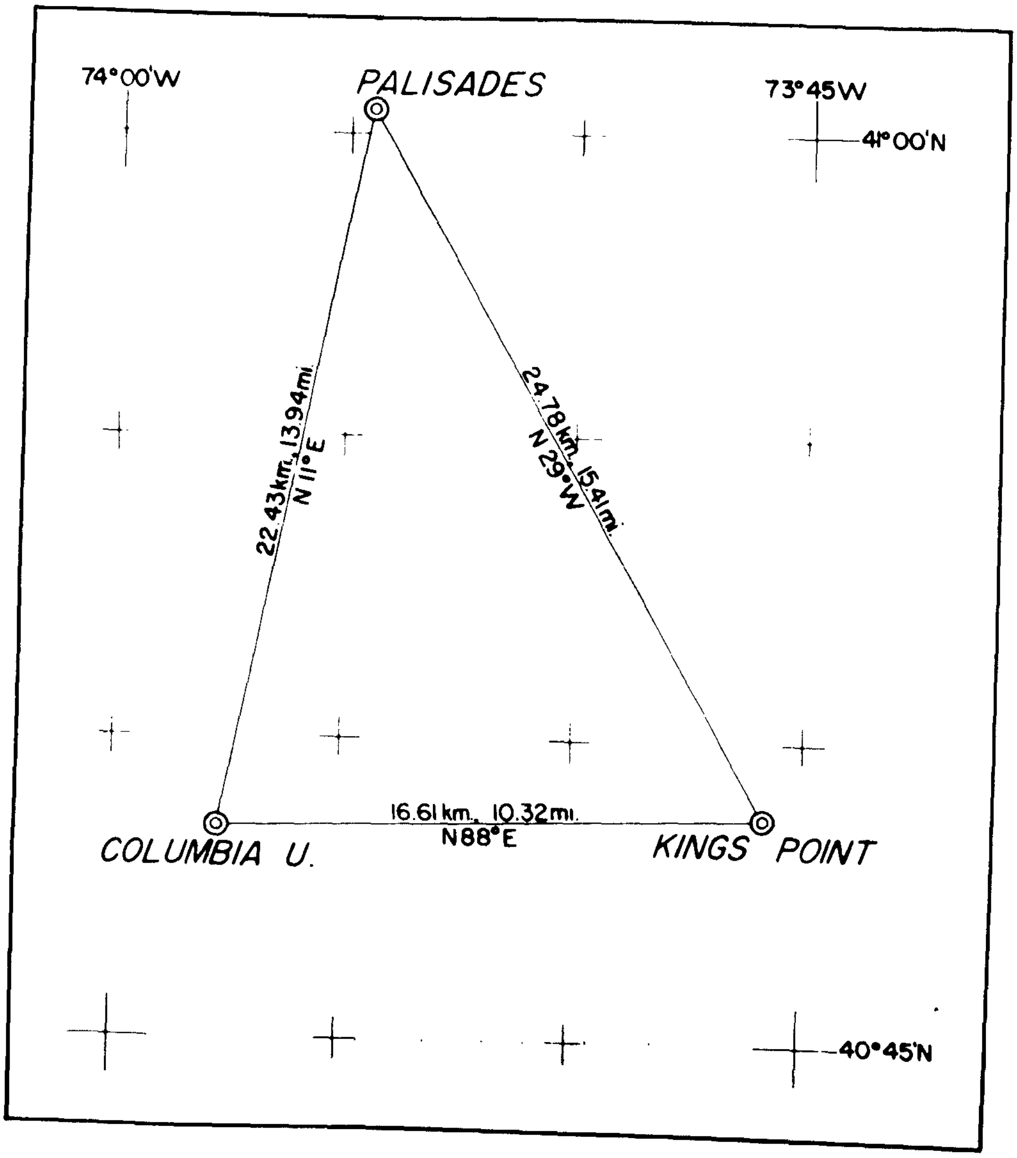
74°00'W
PALISADES
73°45W
41°00'N
22.43km, 13.94mi.
N 11° E
24.78km, 15.41mi.
N 29° W
16.61 km, 10.32mi.
N88°E
COLUMBIA U.
KINGS POINT
40°45'N

Figure 1

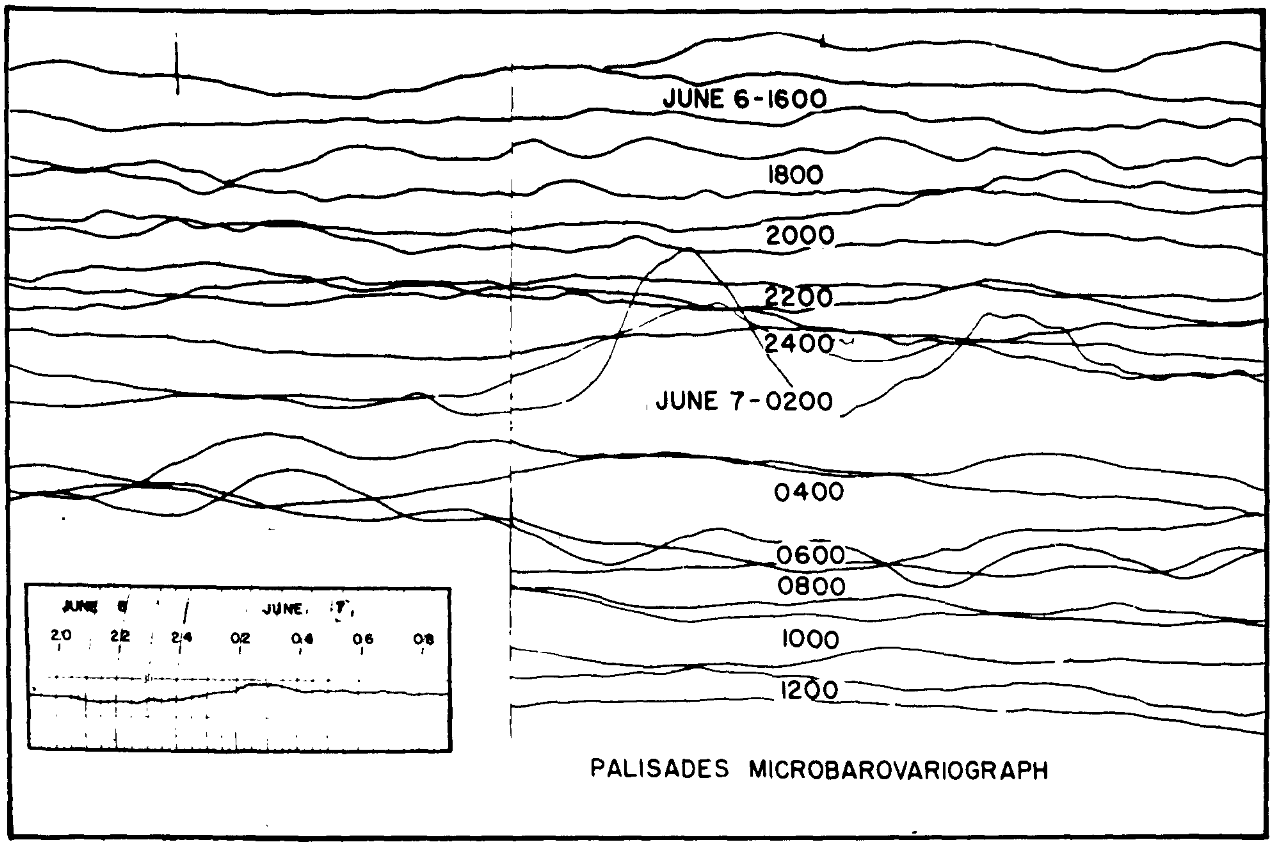

Figure 2. Palisades microbarovariogram (with short-period filter) and Friez microbarogram (inset)

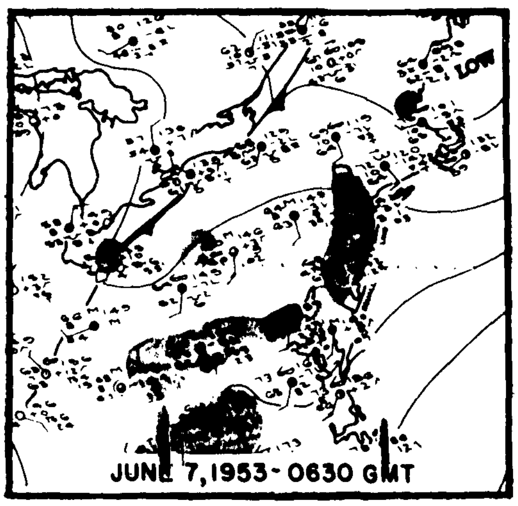

Figure 3

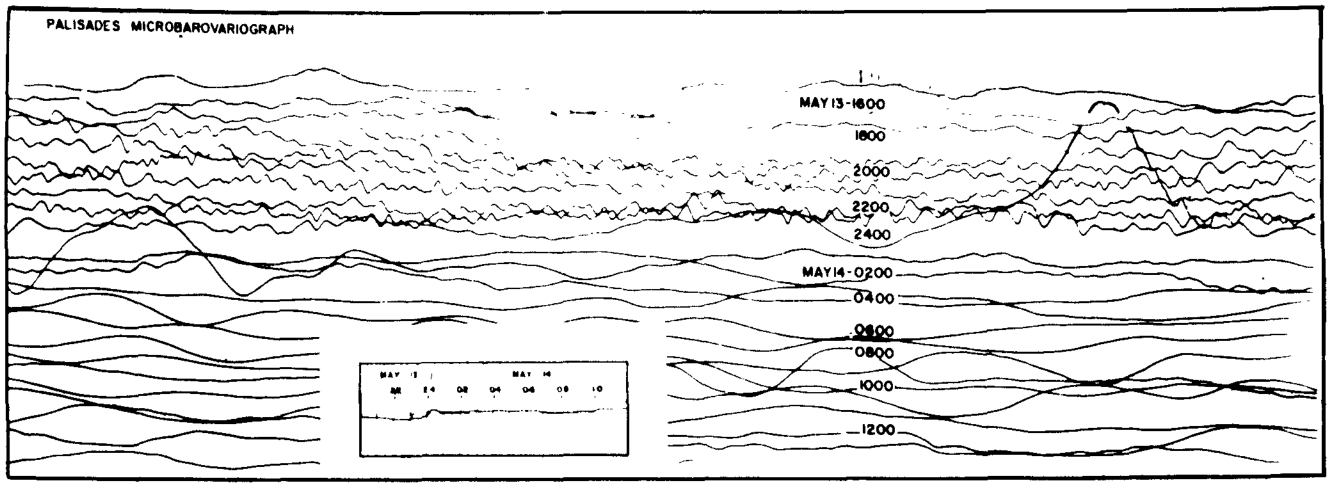

Figure 4. Palisades microbarovariogram and Friez microbarogram (inset)

Figure 5

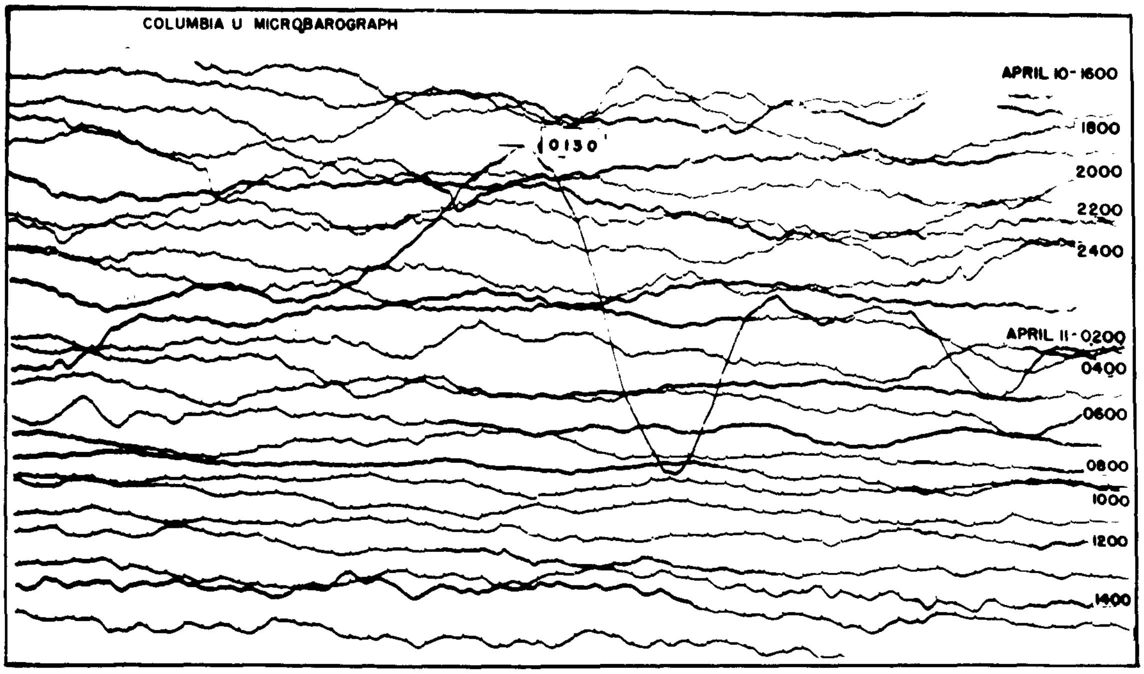

Figure 6. Columbia University microbarovariogram (with short-period filter)

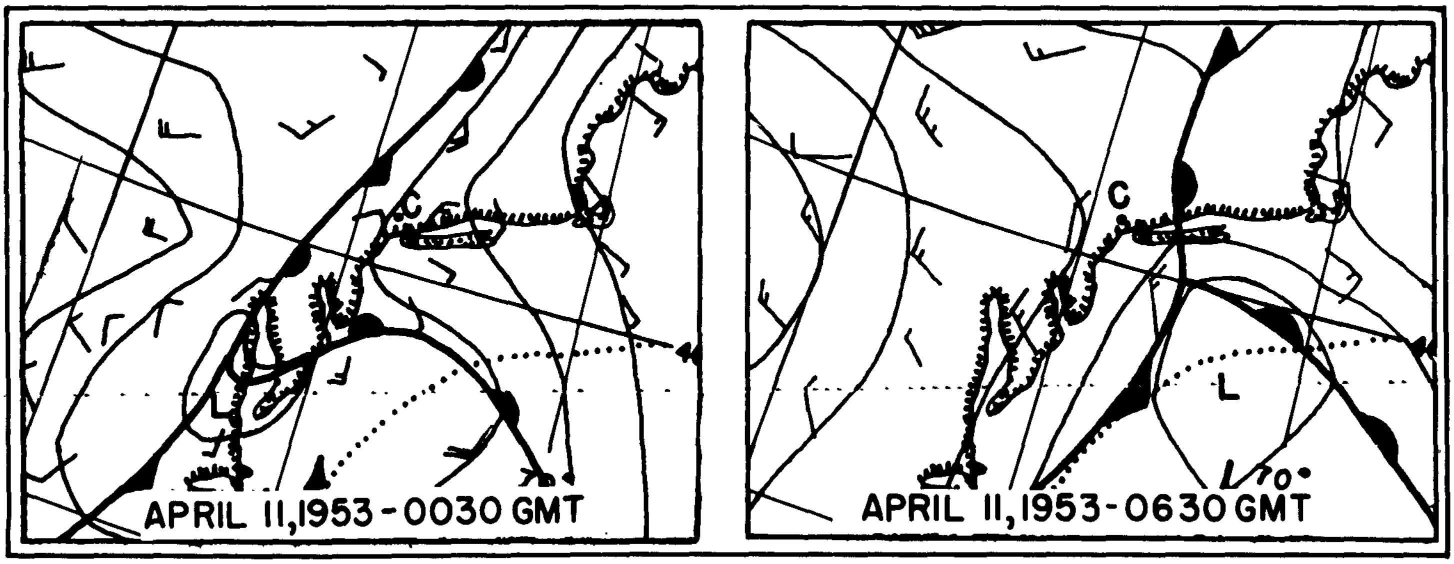

Figure 7

Figure 8

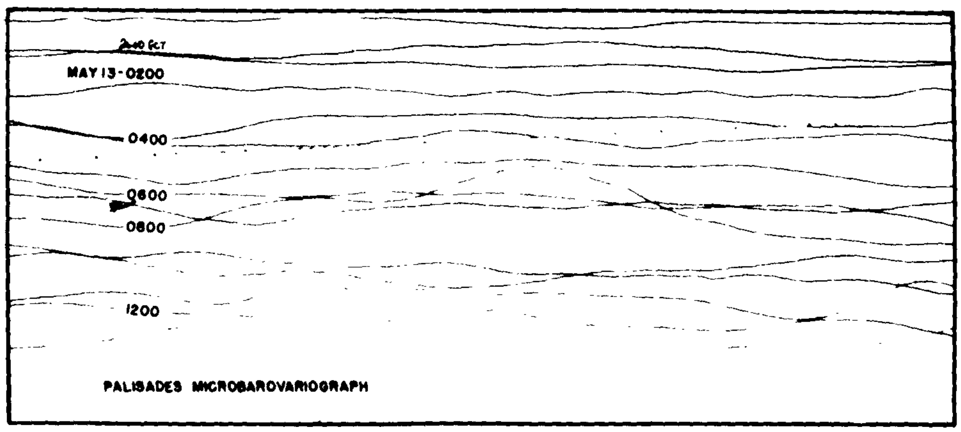

Figure 9. Palisades microbarovariogram (with short-period filter)

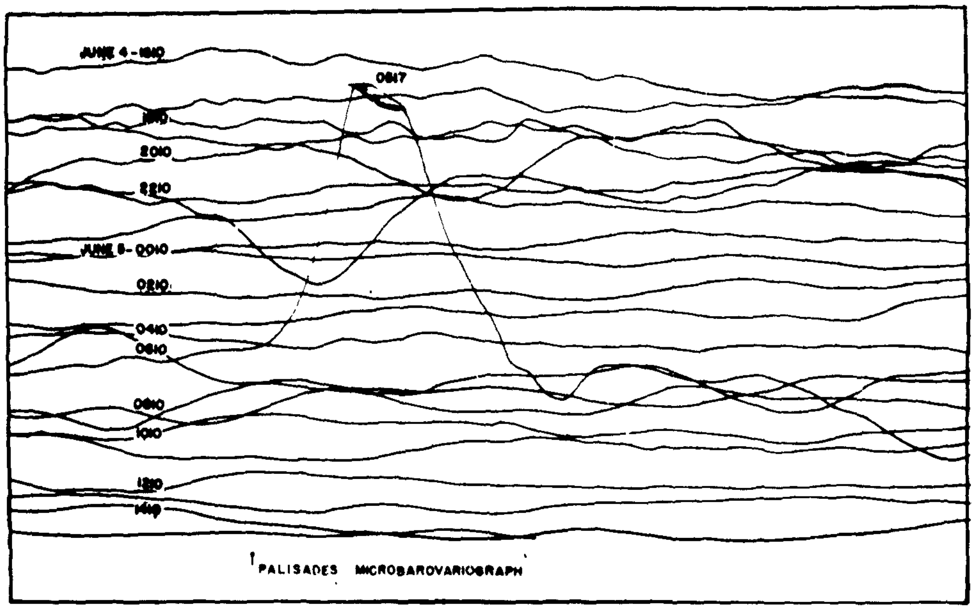

Figure 10. Palisades microbarovariogram (with short-period filter)

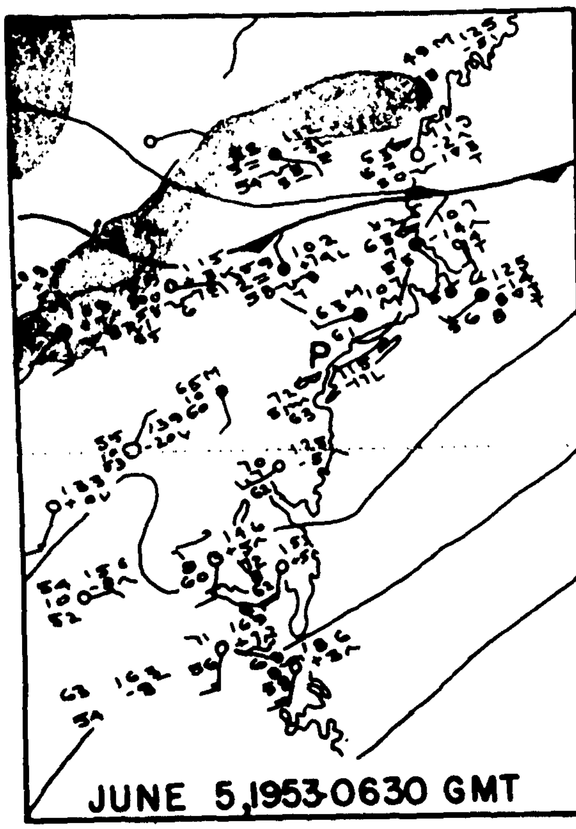

Figure 11

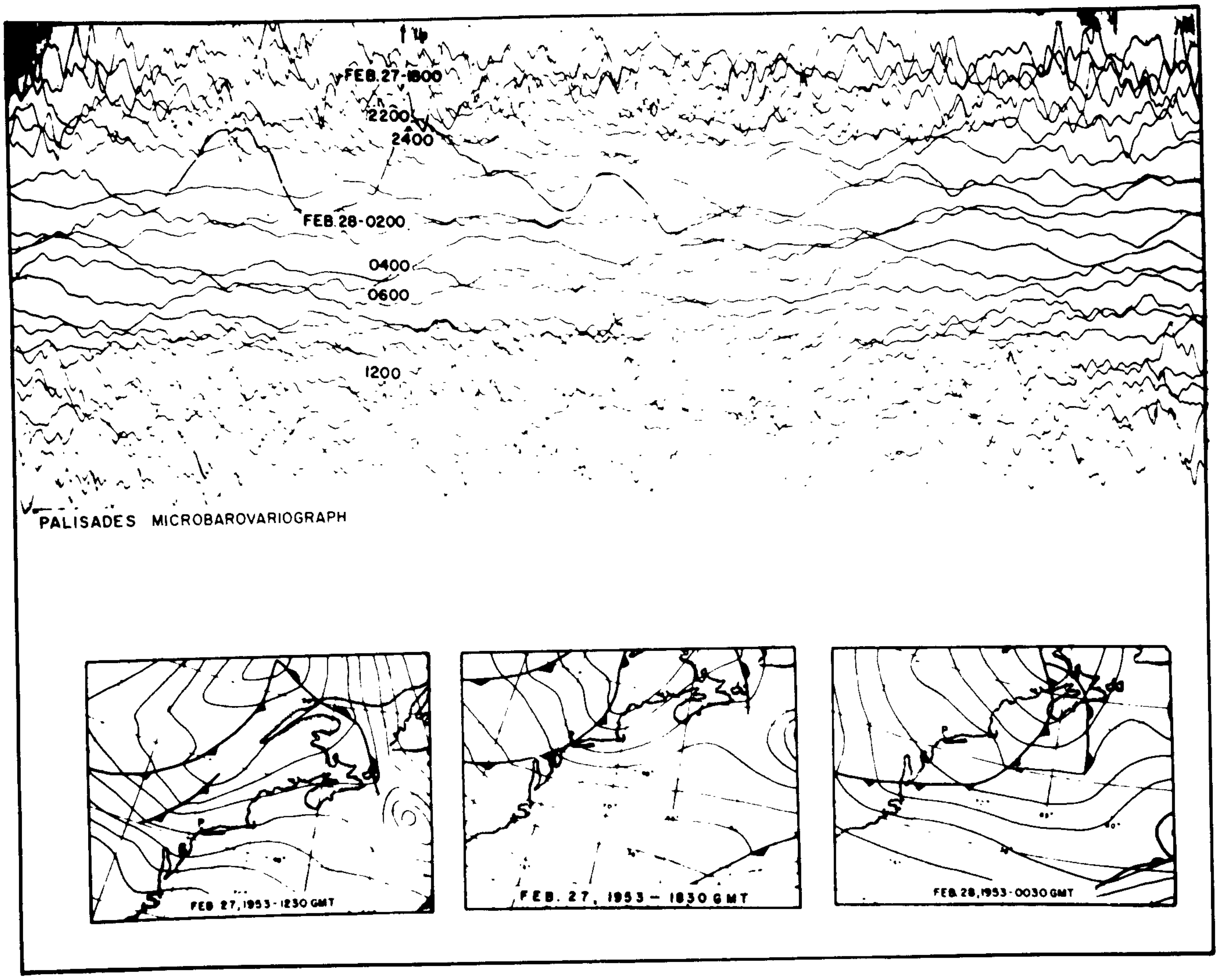

Figure 12. Palisades microbarovariogram (without short-period filter) and synoptic maps of related weather.

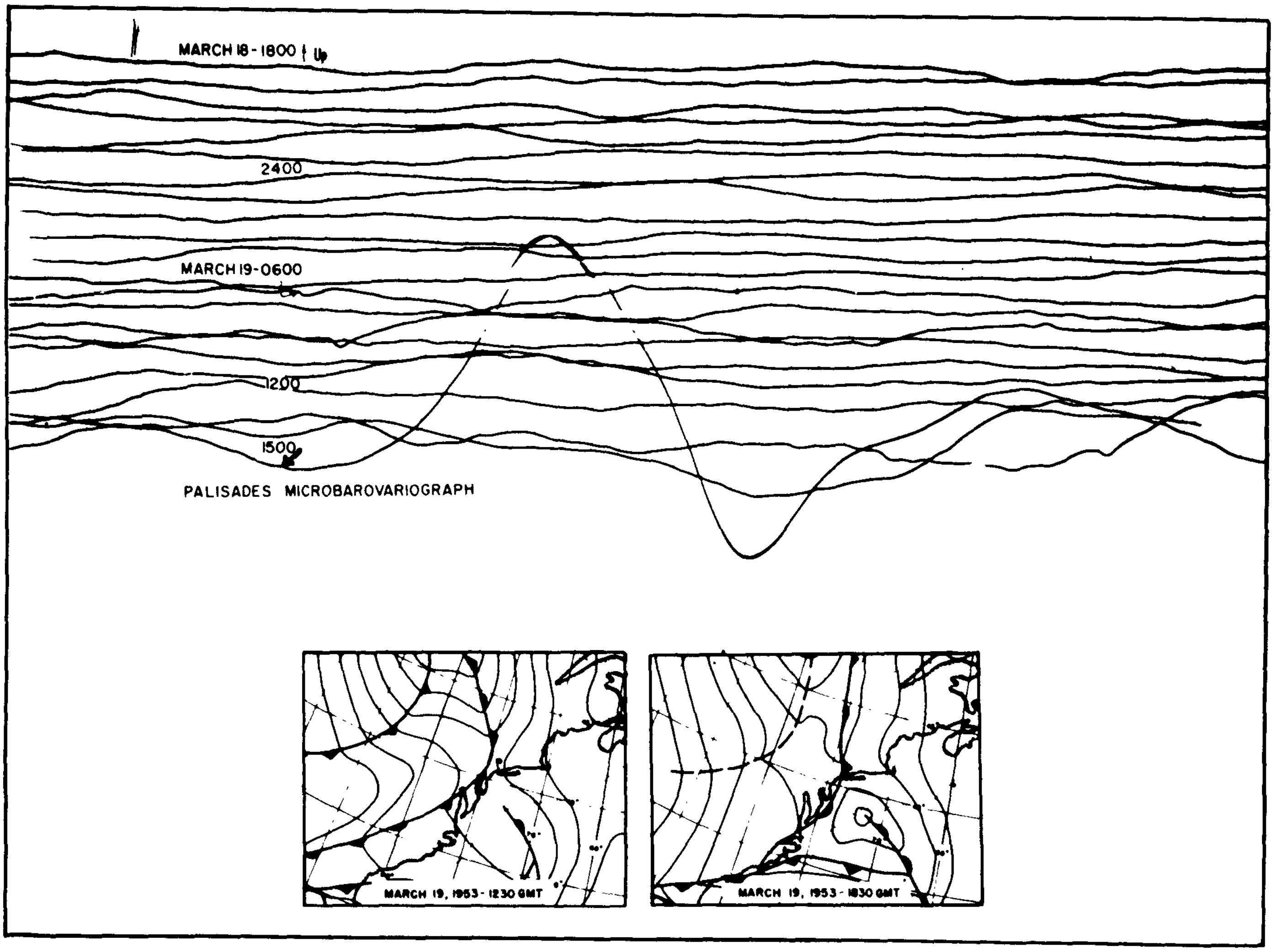

Figure 13. Palisades microbarovariogram (with short-period filter) and maps of related weather